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CONTROL OF CUCUMBER MOSAIC BY ERADICATION OF WILD HOST PLANTS

By S. P. Doolittle, *Pathologist*, and M. N. Walker, formerly *Junior Pathologist*,[1] *Office of Vegetable and Forage Diseases, Bureau of Plant Industry*

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INTRODUCTION

Cucumber mosaic is disseminated in the field by insects and by the handling of the vines incident to the cultivation and harvesting of the crop. In the case of pickling cucumbers the latter factor is of considerable importance, but insects are the chief agency in the spreading of the disease. The greater part of the insect dissemination seems to be due to the melon aphis, *Aphis gossypii* Glover, but the striped cucumber beetle, *Diabrotica vittata* Fabr., and the 12-spotted beetle, *D. 12-punctata* Oliv., are also important as carriers of the disease.

The first attempts to control mosaic consisted in the removal of mosaic cucumber plants as they appeared, together with the use of insecticides to reduce the number of insect carriers. It was found, however, that these methods were of little value in cases where the disease had become well established and where insects, particularly aphids, were present in considerable numbers (*2*).[2]

[1] The writers are indebted to W. W. Gilbert, of the Office of Vegetable and Forage Diseases, for suggestions and advice during the progress of this work.

The Department of Plant Pathology, University of Wisconsin, has cooperated in furnishing land and laboratory facilities necessary for certain phases of the investigations, and certain interested pickle companies and growers have cooperated by furnishing funds and facilities for carrying on the work in the field.

[2] Italic numbers in parentheses refer to "Literature cited," p. 14.

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It was soon realized, therefore, that any effective control measures must be based on a knowledge of the agencies by which the disease was carried over winter. The consequent studies of the overwintering of cucurbit mosaic (*2*, *5*) showed that it was not carried in the soil, nor, so far as could be determined, by insects. Experiments on the transmission of mosaic in the seed of the cultivated cucurbits indicated that this occurs so rarely, if at all, that it can not be considered as a source of infection in the field. As a result of this negative evidence, a study was made of the possible overwintering of the disease on wild host plants.

The earlier investigations of this question proved that the wild cucumber, *Micrampelis* (*Echinocystis*) *lobata* (Michx.) Greene, was susceptible to mosaic and that, unlike the cultivated cucurbits, the disease was carried in the seed of this host (*1*, *5*). (Pl. 1.) Field observations showed that wild cucumber plants affected with mosaic appeared early in the spring and that the Diabrotica beetles fed on this host before cultivated cucurbits were planted and later transmitted the disease from the wild cucumber to the cultivated cucurbits. Surveys during 1919 showed that mosaic wild cucumbers occurred in considerable numbers in districts where mosaic was prevalent. In view of this correlation of the disease on the wild host with the presence of mosaic in the field, it was decided to attempt to control mosaic through the eradication of the wild cucumbers in certain sections where the disease was prevalent in the field. These earlier experiments were located chiefly at Rockland, Wis., and Marengo, Ill.

In each case an area was selected which included a number of cucumber fields in which mosaic was reported to have caused severe injury in previous years. The removal of the wild cucumber plants in these areas was undertaken before cucumbers had been planted in the field, and after the first eradication the areas were again inspected at intervals of 10 to 14 days for the greater part of the season. The wild cucumber is usually found on low, moist ground, but has been used extensively as an ornamental and is often abundant in the vicinity of towns. In the eradication work it was found that the plants were commonest along small streams, in hedgerows, and about farm buildings. Only a small percentage of the plants were found to be affected with mosaic, but these mosaic plants frequently occurred in the vicinity of cucumber fields. All the wild cucumbers were removed throughout the experimental area regardless of the presence of mosaic. Practically all the plants in the area were found during the first inspection, but where large groups of plants occurred along wooded streams or ditches an occasional plant was found during later inspections. In all this work the wild cucumbers were merely pulled out and allowed to remain where they were found.

EXPERIMENTS OF 1920

ROCKLAND, WIS.

Experimental work at Rockland, Wis., in 1920 included an area of approximately one-half square mile. Ten fields in this area were planted to cucumbers, most of the fields being within a radius of one-fourth of a mile of the village of Rockland, which was included

in the experimental section. Seven other fields at some distance from the town were considered as controls on the work. The experiments at Rockland presented peculiar difficulties, as the fields, in many cases, were so closely adjacent to one another that the disease was likely to spread with great rapidity after it once appeared. It was felt, however, that if the disease could be controlled under these circumstances the method would prove practicable in nearly all localities.

In 1920 approximately 2,500 wild cucumber plants were removed at Rockland, about 50 of which showed mosaic. The greater number of plants were found along the LaCrosse River, which bounded one side of the experimental area, and along certain other small streams. Most of the mosaic plants, however, occurred in and about the village and in several cases were close to fields of cucumbers. The 10 experimental fields remained free from mosaic until about July 15, although some of the control fields showed the disease. On August 5, however, two fields were found to be severely affected with mosaic. The disease appeared to spread from these fields to others in the vicinity, and on August 31 the average infection in all fields was 80 per cent. Investigations showed that the fields first affected contained large numbers of mosaic milkweed plants which were infested with the cucumber aphis. As a result of investigations during 1920–1921 (*3*, *5*), it was found that the milkweed, *Asclepias syriaca* L., was a perennial host of cucurbit mosaic, and it was evident that it must be included in the program of eradication. (Pl. 2, *B*.)

MARENGO, ILL.

In experiments at Marengo, Ill., in 1920, the fields were so scattered that it was necessary to include an area of more than 1 square mile in the work of eradication. Most of the land was under cultivation, however, and attention was centered on small streams, fence rows, and the vicinity of farm buildings. The number of wild cucumber plants was few when compared with the Rockland area, but several mosaic plants were found near farm buildings. The fields in the experimental area remained practically free from mosaic throughout the season, although fields in the vicinity were severely damaged by the disease.

PLYMOUTH, IND.

A similar experiment was conducted at Plymouth, Ind., in 1920, through the cooperation of M. W. Gardner, of the Indiana Agricultural Experiment Station. The work there covered an area of about 1 square mile, containing four cucumber fields. A few wild cucumber plants were found, but none showed signs of mosaic. A few mosaic plants appeared in two of the fields at the end of the season, but no serious losses had occurred.

RESULTS OF WORK IN 1920

The results of the work at Marengo seemed to show a distinct reduction in the amount of mosaic as a result of the removal of wild cucumbers. Although no mosaic hosts were found at Plymouth, the results there indicated that the disease might not occur to any extent in districts where the wild cucumber was rare. The results at Rock-

land, however, had shown that at least one perennial wild host, the milkweed, existed outside the cucurbits and indicated that the work must be continued before successful control methods could be established.

EXPERIMENTS OF 1921

ROCKLAND, WIS.

During 1921 the experiments at Rockland, Wis., were continued over approximately the same area as in 1920, but an effort was made to remove all mosaic milkweeds as well as wild cucumbers. No effort was made to remove all healthy milkweeds, but all the plants found were examined and any groups of plants showing mosaiclike symptoms were removed. Since the roots of the milkweed usually lie 8 to 15 inches below ground and extend laterally for some distance, it was not found practicable to dig the plants. The shoots were pulled out and frequent inspections made in order to remove any new shoots which might appear later in the season. An effort was also made to enlist the cooperation of the growers on whose land mosaic plants were found. Where the plants were pulled up, the mosaic milkweeds did not appear to send up new shoots in less than 10 to 15 days, and in dry weather no new shoots developed for some weeks, if at all. In other cases, however, mosaic milkweeds appeared late in the season on cultivated land on which no plants had been found during the early summer. A portion of the 1921 infection in fields at both Rockland and Marengo was traceable to such plants.

The eradication work of 1920 was found to have greatly reduced the number of wild cucumbers at Rockland and only a few mosaic plants were found. Several groups of mosaic milkweeds were discovered, all of which were on land which had previously grown cucumbers. Subsequent observations in various localities have confirmed this fact, both with respect to the milkweed and with other perennial hosts as well. Examination of thousands of milkweeds growing on land which has never been planted to cucurbits has shown only three cases of mosaic. It is probable that the milkweeds are first infected from adjacent mosaic cucumbers through the agency of the cucumber aphis and during the following year act as sources of infection to the cultivated cucurbits. It is, therefore, highly important that both healthy and mosaic milkweeds in the vicinity of cucurbit plantings be destroyed.

The 1921 experiments at Rockland included 17 cucumber fields, all of which remained free from mosaic until August 1. On the final inspection on August 24 the average infection per field was approximately 25 per cent, as compared with 80 per cent in 1920. The effect of the removal of mosaic milkweeds was apparent in the case of 3 fields in which such milkweeds occurred in 1920. In that year the cucumber plantings in all these fields were practically destroyed by the disease early in August. In 1921 the same fields were planted to cucumbers, but the milkweeds were removed. On August 24 none of the fields showed more than 10 per cent of mosaic. These results at Rockland showed an apparent reduction in the amount of mosaic, but as there appeared to be a marked decrease in the mosaic infection in most sections throughout the State, there was a possibility that more than one factor was involved. At the

end of this season's work it was realized that it was almost impossible to procure control fields which would give a just basis for comparison with fields in the experimental area. The fields used for the eradication experiments were all located in and about the village of Rockland, and any fields in the vicinity used for controls were necessarily situated at some distance in the surrounding country. It is a recognized fact, however, that cucumber fields located at a distance from towns rarely suffer as severely from mosaic as do those which are near by, probably because of the greater number of mosaic host plants which occur in the vicinity of the gardens and small plantings which are concentrated at such points. During the five years of the work at Rockland it was evident that the fields situated a mile or more from the village rarely suffered severely from mosaic. After 1921, therefore, no attempt was made to use separate control fields as a criterion of the success of the work. The difficulties encountered in controlling the mosaic during the period of 1920–1922 demonstrated that most fields in the experimental area would be severely affected by mosaic under ordinary conditions and indicated that any marked reduction in the amount of mosaic could properly be considered the result of the eradication work if such a reduction continued during successive seasons.

MARENGO, ILL.

The continuation of the experiments at Marengo, Ill., in 1921, showed that the work of 1920 had greatly reduced the number of wild cucumber plants. Mosaic milkweeds were found at a few points, and mosaic infections which occurred in two fields late in the season were traced to this source. Very little mosaic appeared in the experimental area, but the disease did so little damage in the general vicinity that no definite conclusions could be drawn as to the results of the work.

EXPERIMENTS OF 1922

ROCKLAND, WIS.

The experiments of 1920 and 1921 at both Rockland and Marengo showed that any complete eradication of wild host plants over an extended area offered such great practical difficulties as to make such a method of doubtful value to the grower under general field conditions. At the same time observations had shown that it was probable that most of the infection on the cucurbits came from near-by sources, although in case of the wild cucumber there is a possibility that the striped beetles may carry infection over considerable distances (*5*, *6*). It appeared, however, that the chances of such infection were so slight as to be outweighed by the expense and difficulties encountered in any attempts at removing all possible sources of infection over a wide area. It was decided, therefore, to test the possibilities of controlling the disease by removing only such wild host plants as occurred within 50 to 100 yards of the individual fields.

The work at Rockland was carried on in this manner and all milkweeds in the vicinity of the fields were removed, whether healthy or affected with mosaic. A number of mosaic milkweeds were found, but most of them occurred at points where mosaic plants were found

in 1921, and in most cases the number of plants seemed considerably reduced. Practically no wild cucumber plants were found during 1922. After the first eradication no mosaic milkweeds appeared except in one case, but 8 of the 16 fields in the area showed traces of mosaic on July 12. The first appearance of the disease was in a field which contained a large number of mosaic milkweeds in 1920 and which the grower had left practically uncultivated, making it difficult to prevent the appearance of some mosaic plants. The infection of the other fields, however, was not traceable to this source. The disease progressed gradually throughout the season, and on August 28 the average infection per field was approximately 50 per cent, or more than twice that of the previous year.

Since practically no mosaic milkweeds or wild cucumbers had appeared since June 15, a search was made for other possible wild host plants, and evidence was obtained which indicated that the cultivated ground cherry, *Physalis pubescens* L., was susceptible to cucumber mosaic (*4*, *11*). Further observation showed that two species of wild perennial ground cherry, *P. heterophylla* Nees and *P. subglabrata* Mackenzie and Bush, occurred in considerable numbers, and later experiments proved that both species were susceptible to cucumber mosaic (*11*). It seemed probable, therefore, that some of the infection might be traced to this source.

MARENGO, ILL.

The size of the experimental area at Marengo, Ill., was reduced about one-half in 1922. It contained eight fields, and the work was carried on in the same manner as at Rockland, the eradication being confined to the immediate vicinity of the fields. A number of mosaic milkweeds were found at one or two points, but they were much fewer in number than at Rockland. Practically no mosaic occurred in the area in 1922, but, since little had occurred in the previous two years and other fields in the vicinity showed little infection, no conclusions could be drawn from the work.

The experiments of 1921 and 1922 showed that mosaic was not sufficiently prevalent to make this section suitable for conclusive experiments on the control of the disease, and the work was discontinued after 1922. The experiments at Marengo, however, indicated a direct correlation between the presence of mosaic on wild host plants and its occurrence in the field. The comparatively few mosaic hosts found at Marengo were accompanied by a correspondingly slight occurrence of the disease in the field, whereas at Rockland the greater amount of mosaic on the wild hosts was coupled with severe losses each season.

EXPERIMENTS OF 1923 AT ROCKLAND, WIS.

As a result of experiments based on observations made in 1922, it was found that cucurbit mosaic was transmissible to the two species of perennial Physalis mentioned above, *P. heterophylla* and *P. subglabrata*, by means of the cucumber aphis (*11*). (Pl. 3.) It was also found that the mosaic occurring on these hosts in the field was transmissible to the cucumber by this insect, and it was evident, therefore, that they were factors in the overwintering of the disease.

This fact was of particular interest, since Gardner and Kendrick (*7*, *8*, *9*,) had shown that these same species of Physalis were important factors in the overwintering of tomato mosaic.

In the eradication experiments of 1923, therefore, an attempt was made to remove all wild physalis plants in the vicinity of the cucumber fields at Rockland; together with all milkweeds and wild cucumbers. It was found, however, that the work of the previous seasons had resulted in practically eradicating the latter host in the vicinity of most of the fields. A large number of perennial physalis plants were found, however, many of which were affected with mosaic. These plants presented more difficulty in their removal, as they were usually small and when intermixed with other weeds were not easily located. Eleven fields were included in the experiments of 1923. A trace of mosaic appeared in two cucumber fields on July 11 and the mosaic plants were removed, together with a few suspected plants in other fields. No more mosaic was found until the inspection of July 31, when one field showed 10 per cent. In this field, which was somewhat isolated, the disease spread with considerable rapidity, but it did not develop in the other 10 fields until late in the season. On August 27 the badly infected field showed 60 per cent of mosaic, whereas the remaining 10 fields showed an average infection of less than 10 per cent. A comparison of fields planted on the same land in 1922 and 1923, as shown in Table 2, indicates the striking reduction in the amount of mosaic during the latter season.

The season of 1923 was abnormally dry, which checked the growth of new shoots of both milkweeds and physalis plants and thus favored the work of eradication. The seasonal conditions, however, did not seem to be responsible for the apparent control of the disease, since a normal number of aphids and cucumber beetles were present in the fields, and the rapid progress of the disease in the single field mentioned above was evidence that the agencies of disease transmission were present. It seemed probable, therefore, that the sudden reduction in the amount of mosaic in 1923 was partly due to the cumulative effect of the eradication of the wild cucumber and milkweeds from 1920 to 1922, together with the removal of the previously unsuspected mosaic physalis. It was felt, however, that the results must be repeated before they could safely be ascribed as entirely due to the removal of the wild hosts.

EXPERIMENTS OF 1924 AT ROCKLAND, WIS.

The same area was used at Rockland in 1924, but 14 fields were included in the experiments. A large number of mosaic physalis plants were again found, but the milkweeds and wild cucumbers had practically disappeared. No mosaic developed in any of the fields until July 30, when two fields showed a trace of the disease. On August 19 four fields showed from 15 to 40 per cent of mosaic, but the remaining fields were practically free from the disease, the average infection for all fields being 11 per cent. A severe hailstorm destroyed six of the fields during the latter part of August, so that complete data could not be obtained after that date, but a later inspection of the remaining fields showed that the disease had done little damage after the inspection of August 19.

SUMMARY OF RESULTS AT ROCKLAND, WIS., 1920–1924

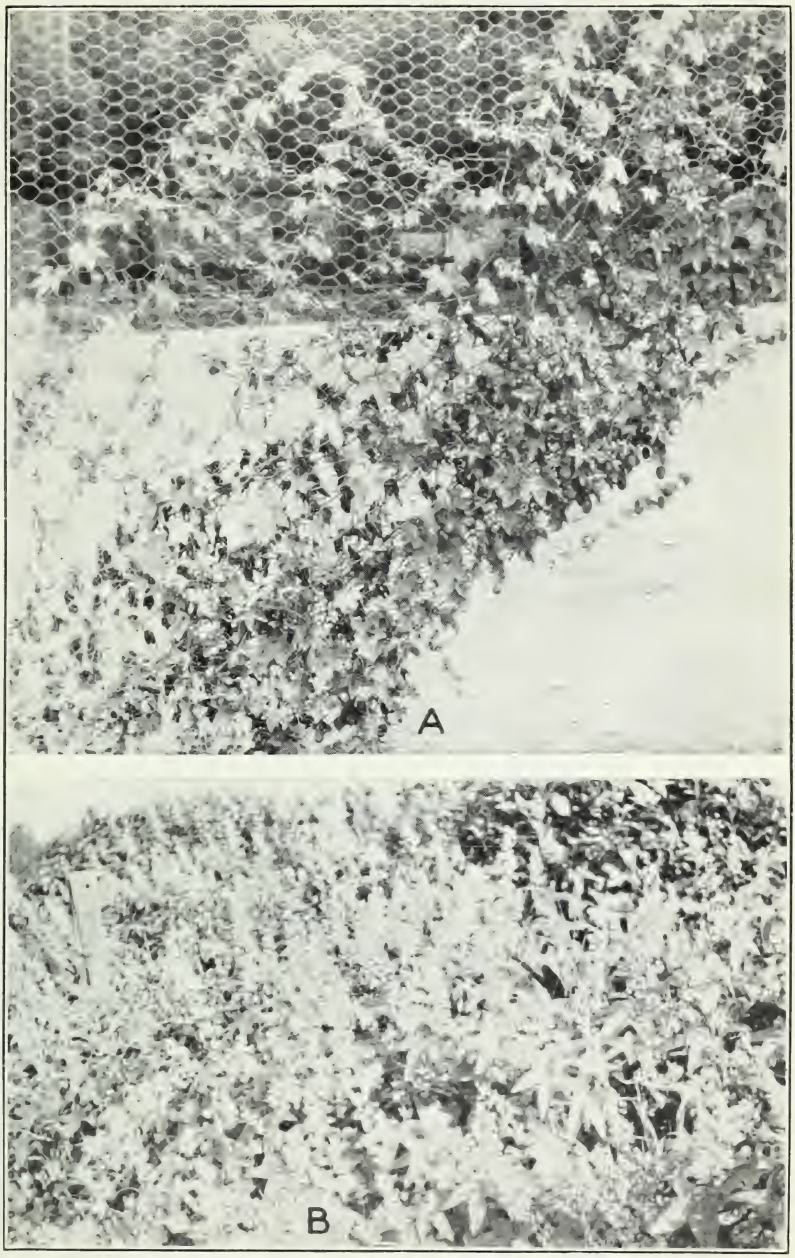
The results of 1924, together with those of 1923, show what appears to be an actual control of cucurbit mosaic through the removal of wild host plants. Table 1 gives a comparison of the losses from mosaic in the experimental area from 1920 to 1924, and it will be seen that the damage during the last two seasons was of little economic importance. The actual losses from mosaic were less than is indicated by the field averages, since the fields varied in size from ⅛ to 1½ acres and in many cases the heaviest mosaic infection in 1923 and 1924 occurred in the smallest fields. When comparison is made on the basis of total plants infected with mosaic, it will be seen that the loss in 1923 and 1924 was negligible.

TABLE 1.—*Percentage of mosaic in cucumber fields in experimental area at Rockland, Wis., 1920–1924*

Date observed	Number of fields in area	Average percentage of mosaic per field	Percentage of total plants in area affected with mosaic
Aug. 31, 1920	12	80	65
Aug. 24, 1921	17	20	15
Aug. 24, 1922	18	41	37
Aug. 27, 1923	13	6	2
Aug. 19, 1924	14	11	5

The results of 1923 and 1924 are the only ones which can properly be considered as typical of the possible results from the eradication of wild host plants at Rockland, since our knowledge of the number of wild host species was increased each year during the period from 1920 to 1922. When the work was begun in 1920 it was supposed that the wild cucumber, *Micrampelis lobata*, was the only wild host to be feared. The work of that year, however, showed that the milkweed, *Asclepias syriaca*, was even more important at Rockland than the wild cucumber. During 1921 and 1922 a further study of the situation showed that two perennial wild species of ground cherry, *Physalis subglabrata* and *P. heterophylla*, were also a means of overwintering mosaic, and at Madison it was also found that the catnip, *Nepeta cataria* L., was occasionally infected with the disease (*5*, *10*). The work of 1923 and 1924 was based on the removal of these plants together with a further survey for other wild hosts of the disease. So far, no other perennial host plants have been found in this region, and the results of the last two seasons indicate that those mentioned above are the chief sources of mosaic infection in the section about Rockland. The success of the work of 1923 and 1924 was partly a result of the earlier experiments, since the previous eradication work had practically eliminated all mosaic milkweed and wild cucumber plants and at the same time extended our knowledge of the host range of the disease.

The reduction in the amount of mosaic seems directly attributable to the removal of wild host plants about the fields rather than to any abnormal reduction in the number of insect carriers or to any



MOSAIC AND HEALTHY WILD CUCUMBER PLANTS

A.—Mosaic wild cucumber plants, *Micrampelis lobata*. Madison, Wis., August, 1921
B.—Healthy wild cucumber plants, showing habit of growth during flowering period. Sparta, Wis., August, 1925

MOSAIC POKEWEED AND MILKWEED PLANTS

A.—Pokeweed plant, *Phytolacca decandra*. Madison, Wis., August, 1923
B.—Milkweed plant, *Asclepias syriaca*. Madison, Wis., August, 1922

MOSAIC PLANTS OF PHYSALIS SPECIES

A.—Physalis heterophylla. Madison, Wis., August, 1925
B.—Physalis subglabrata. Madison, Wis., 1925

seasonal variation in climatic conditions. The variations in weather conditions during both 1923 and 1924 were duplicated at some time during earlier years, and the insect carriers of the disease were normally abundant. Furthermore, a comparison of the amount of mosaic in fields planted on the same land for several seasons shows a marked reduction in the amount of mosaic during 1923 and 1924. Table 2 includes all of the fields which can properly be compared in this regard.

TABLE 2.—*Percentages of mosaic in fields planted during successive seasons at Rockland, Wis.*

Field No.	Percentage of mosaic at end of season				
	1920	1921	1922	1923	1924
2	[1]	20	10	1	3
3	100	[1]	85	0	15
4	100	60	[1]	10	5
5	[1]	50	100	1	25
15	80	25	50	1	8
19	100	[1]	100	2	50
21	55	[1]	20	0	0
25	80	[1]	60	2	0

[1] Field not planted to cucumbers.

In the case of fields 3, 4, 5, 15, and 19, mosaic milkweeds or ground cherries originally were present in the fields and in some cases these wild hosts were so numerous that the land should not have been planted to cucumbers after 1921. Even under these conditions, however, a continued effort to keep down the wild hosts resulted in a marked reduction in the amount of mosaic during the later years of the experiment. All of the evidence, therefore, seems to warrant the conclusion that the reduced infection was the direct result of the eradication of the wild hosts, particularly in view of the definite results obtained in similar experiments on experimental plots at Madison, Wis.

EXPERIMENTS AT MADISON, WIS., 1916–1924

Experiments with single fields at Madison, Wis., have proved definitely that mosaic may be controlled by the eradication of wild host plants and have confirmed the results obtained in the more extensive experiments at Rockland. The principal experiments at Madison were conducted on an isolated field which had been used for mosaic studies continuously since 1916. This plot had been planted to cucumbers each year from 1916 to 1923, and the field had been practically 100 per cent mosaic by the middle of August each season. Mosaic milkweed plants were abundant in the field, which had furnished the first evidence of infection from this host (*5*), and mosaic physalis and catnip were also present. The plot was at least half a mile from other cucurbits and therefore offered an excellent opportunity to test the effect of eradication, since there was no likelihood of infection from other fields, and the continued severity of the mosaic infection in preceding years furnished a definite basis for the interpretation of the results.

In both the 1923 and 1924 experiments the first eradication was made between June 12 and June 15, shortly before planting, and the field and vicinity were then regularly inspected every three to seven days until August 25.

In 1923 the disease did not appear in the field until August 19, and only 7 per cent of the plants were affected on September 7. In 1924 the results were much the same, as only 12 per cent of the plants were affected on September 1. As shown by Table 3, these figures are in sharp contrast with the early and severe infection which occurred during the six preceding years.

TABLE 3.—*Effect of eradication of wild hosts on occurrence of mosaic in experimental plot at Madison, Wis.*

Year	Date of first infection	Percentage of mosaic late in season		Date observed
		No eradication	Eradication	
1916	July 7	80	----------	Aug. 9
1917	July 19	100	----------	Aug. 19
1918 [1]	----------	----------	----------	----------
1919	July 8	100	----------	Aug. 13
1920	July 12	100	----------	Aug. 16
1921	July 17	100	----------	Aug. 21
1922	June 29	100	----------	July 30
1923	Aug. 19	----------	7	Sept. 7
1924	Aug. 20	----------	12	Sept. 1

[1] In 1918 severe infection was reported but was not observed by the writers.

Similar results were also obtained during 1924 and 1925 with another plot which had formerly grown mosaic cucurbits. This field was severely damaged by mosaic for three years previous to 1924, the infection being between 60 and 80 per cent each season. In this experiment a number of mosaic milkweeds and wild cucumber plants were removed about the field, and these measures were again followed by the practical elimination of mosaic. No infection occurred in 1924, and in 1925 only 3 per cent of the plants showed mosaic on August 21. In this experiment a control plot was planted in 1924 at a distance of one-third of a mile on land on which severe mosaic infection had occured in 1919, 1920, and 1922, and where mosaic milkweeds were known to occur. This control plot was 100 per cent mosaic on August 15. In all these experiments there was the normal infestation of insect carriers throughout the season. In view of these definite results, the belief that cucumber mosaic can be controlled by the eradication of the wild host plants of the disease appears to be justified.

EXPERIMENTS AT ANNA, ILL., 1923

In addition to the foregoing experiments, preliminary work was undertaken in the vicinity of Anna, Ill., in the extreme southern portion of the State, in 1923. The pokeweed, *Phytolacca decandra* L., which is known to be a perennial host of cucumber mosaic, but which does not occur commonly in Wisconsin (*5*), appeared to be the only known host of importance in this section. Mosaic poke-

weeds were abundant, however, and in many cases were found to occur in and about the seed beds. Field observations indicated that the infection in the field could be traced to this source, and eradication experiments were conducted on six farms in 1923 through the cooperation of L. S. Foote, the local county agent. Mosaic had been severe in all these fields during the preceding season and in earlier years. At the end of the season of 1923, late in July, four of the six fields showed losses of only 10 to 20 per cent from mosaic as against an average loss of 60 per cent in 1922. In the two remaining fields the eradication work had been abandoned by the growers early in the season, and both showed losses of from 40 to 50 per cent from mosaic, as did other fields in the immediate vicinity. These experiments, though only of a preliminary nature, indicated that in sections where the pokeweed occurs its eradication may result in a considerable reduction in the amount of mosaic in the field.

RECOMMENDATIONS FOR MOSAIC CONTROL

The experiments at Madison have demonstrated that mosaic can be controlled in an isolated field by the removal of the wild host plants, and the work at Rockland has further shown that this method of control may greatly reduce the loss from mosaic when applied to larger areas. The Rockland section has presented a more severe test of such control measures than is found in most cucumber-growing districts, since the fields were grouped closely in and about the town, all of them being within a radius of half a mile. Such an arrangement presented the difficulty that a single infected field might act as a source of infection to several others, and to control the disease, therefore, it was essential that most of the fields remain practically free from mosaic until late in the season. Mosaic host plants were abundant, as they are usually more numerous about towns where there are many gardens, and their eradication, therefore, was more difficult than it would have been in the case of fields more widely scattered over the surrounding country. In addition to this, no attempts were made to control either the aphis or the striped beetle, although such measures might have simplified the problem to a considerable extent. In several cases, also, cucumbers were persistently planted on land infested with mosaic milkweeds, thus furnishing a possible source of infection for other fields. In view of the results obtained under such conditions it is believed that the control of the disease is a practical possibility in most sections if the following practice is adopted.

Cucumbers should not be planted continuously on the same land. The rotation of the cucumber crop is advisable for the control of other diseases, such as anthracnose and scab. In the case of mosiac it is necessary to remove the crop from a location where the gradual accumulation of a reservoir of infection in perennial weed hosts affected with mosaic would serve as a source of infection during following seasons.

The cucumber field should be located at a distance from the farm buildings and vegetable garden. Such isolation is important because it has been found that the wild cucumber, milkweed, and ground cherry are commonly found about farm buildings and that mosaic

plants of these species are more likely to occur near garden plots as a result of earlier infection from cultivated cucurbits.

If possible the field should be surrounded by other cultivated crops, since their cultivation will reduce the number of wild hosts about the field. It has also been found that fields so situated are less likely to be infested with insect carriers of the disease.

All plants which are known to carry mosaic over winter should be removed from the field itself and from all land within a radius of 50 to 75 yards. This includes the wild cucumber, milkweed, wild ground cherry (*Physalis*), pokeweed, and catnip. All of these hosts may not occur in one locality, but some of them appear to be common in most cucumber-growing sections in the Central and Eastern States. In the case of the wild cucumber, milkweed, ground cherry, and catnip, the plants should be dug out if they are not too abundant, but it has been found that if the shoots are pulled up as fast as they appear the plants eventually will die out. Where pokeweeds occur it is best to cut down as far as possible into the large roots and cover the cut surface with salt. If the field receives the clean cultivation that cucumbers require, many of the wild hosts will be removed in the process. The first eradication should be made just before planting, and the field and vicinity should be inspected regularly thereafter at intervals of 3 to 10 days. Frequent inspections are essential owing to the fact that perennial hosts such as the milkweed and ground cherry will often fail to send up shoots for some time and then suddenly develop them in large numbers. Experience has shown that such eradication work in the case of the average field requires only 5 to 10 hours of additional labor during the season.

All cucumber plants in which mosaic appears early in the season should be removed in order to prevent the further spread of the disease.

Since the disease is carried from the wild hosts to the cucumber by means of insects, the field should be sprayed or dusted regularly in order to keep down plant lice and cucumber beetles.

The writers believe that if the above-described procedure is carefully followed the losses from mosaic in the average field can be reduced to a point where they are not of serious importance. It must be realized, however, that where fields lie close together it is almost essential that all the growers cooperate in removing the sources of infection about their fields.

SUMMARY

Field experiments on the control of cucumber mosaic by the eradication of the wild host plants on which it overwinters were conducted in Wisconsin and Illinois from 1920 to 1924. When these experiments were undertaken it was known that mosaic was carried in the seed of the wild cucumber, *Micrampelis* (*Echinocystis*) *lobata*, and as the work progressed it was also found that the disease overwintered in the roots of the following perennials: Milkweed (*Asclepias syriaca*), pokeweed (*Phytolacca decandra*), ground cherry (*Physalis heterophylla* and *P. subglabrata*), and catnip (*Nepeta cataria*). Certain of these hosts occur in all the cucumber-growing sections of the Eastern and Central States.

Mosaic is transmitted from the wild cucumber to the cultivated cucurbits by the striped beetle, *Diabrotica vittata*, and to a lesser extent by the 12-spotted beetle, *D. 12-punctata*. The melon aphis, *Aphis gossypii*, acts as the chief agency of dissemination from the other wild host plants.

The experiments included groups of 8 to 17 fields in localities where mosaic had been prevalent in previous years. In the earlier experiments, attempts were made to remove all the mosaic host plants occurring in areas of one-half to one square mile. It was later found, however, that it was apparently equally effective to confine the eradication to those hosts which occurred in or within 50 to 75 yards of the individual fields, since most of the mosaic infection on the wild hosts occurred in the vicinity of land which had previously grown mosaic cucurbits. Under this system all the plants of known host species were removed regardless of the occurrence of mosaic. The eradication was begun at the time cucumbers were planted and the inspections were repeated at intervals of 10 to 15 days during the season.

The fact that the mosaic infection on the perennials such as the milkweed and *Physalis* spp. occurred almost entirely on land which had grown cucumbers indicated that they had originally been infected from the cultivated cucurbits and emphasized the importance of rotation of the crop. It was also evident that it is essential to keep the fields free from such hosts in order to prevent their becoming infected with mosaic and acting as sources of infection to succeeding crops. Where the shoots of these hosts were pulled out rapidly throughout the season it was found that they practically disappeared by the end of the second year.

The experiments of 1920 to 1922, conducted in both Illinois and Wisconsin, were inconclusive, due partly to a lack of sufficient mosaic infection in the Illinois trials and to the constant discovery of new hosts during the early part of the work. In 1923 and 1924 the experiments were continued only at Rockland, Wis., where all the known hosts were abundant excepting the pokeweed. The results of these years showed that cucumber mosaic can be controlled by this method under difficult field conditions. The average infection in the Rockland area during the period from 1920 to 1922 was approximately 39 per cent, while in 1923 and 1924 it was reduced to slightly more than 3 per cent.

Similar experiments were conducted on a single field at Madison, Wis., in which 100 per cent of mosaic had occurred each year from 1916 to 1922. In 1923 and 1924, following the eradication of mosaic milkweeds and physalis, the percentage of infection was reduced to approximately 10 per cent during both seasons.

In view of these results it is believed that cucumber mosaic can be controlled by the methods outlined in this bulletin, if the work is done with care and continued throughout the season.

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